Amendments to the Specification including Abstract

The changes are extensive, so a clean copy and a marked up copy are included in this section. I have also enclosed a CD with a Microsoft word version of the amended specifications with the track changes turned on, so you can view all revisions on a computer and may use to replace the existing electronic copy.

Clean copy is first

Marked up copy second

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SOLAR HEAT TRANSFER SYSTEM (HTPL), High Temperature Pressurized Loop

BACKGROUND OF INVENTION

This invention pertains to collection and delivery of heat from a roof or ground mounted solar collector panel to a hot water storage tank via the use of a pressurized fluid loop and a single pump. The pressurized loop system utilizes a water/antifreeze mixture or other suitable fluid and is circulated via a pump. In addition, the system is protected from over-temperature and over-pressure if the circulating pump power is lost or the controller turns the pump off. The high temperature fluid heat transfer loop allows for a smaller heat transfer area and hence more compact, hot water tank heat exchanger which adapts to existing hot water tanks and is double walled to prevent cross contamination of potable water and the antifreeze heat transfer fluid in the solar collector loop. The system includes a small diameter, i.e. 2 inch, flexible insulated umbilical containing both electrical and approximately 3/8 inch outside diameter fluid tubing, to go between the hot water tank and the solar collector for ease of installation. The saving in both complexity and materials for heat exchangers, piping, insulation, and the self-protection from freezing, overheating and over pressure, makes this solar collector system unique.

PRIOR ART

Most common solar collector systems are unpressurized and use a heat exchanger external to the water tank to exchange heat from the unpressurized solar loop to the city water pressure in the hot water tank. Unpressurized solar collector heat transfer loops are limited to the boiling point of water/antifreeze mixtures, typically 50/50, at atmospheric pressure which is approximately 220 degrees Fahrenheit. A water antifreeze mixture of approximately 50/50, pressurized to fourteen PSI (or approximately two atmospheres) in the solar collector loop will not boil until 265 degrees Fahrenheit. The higher operating temperature in the solar collector loop allows for smaller surface area internal tank heat exchangers to be utilized, which do not disturb the normal tank stratification. Using an internal tank double walled heat exchanger also eliminates the pump from the hot water tank through the external heat exchanger. Circulating water from the hot water storage tank, through the external heat exchanger disturbs the stratification of the hot water tank, hot on top and cooler on the bottom. It is important not to disturb the normal tank stratification because it decreases the normal gas or electric heater efficiency.

Some solar collectors use city water pressure and flow the potable city water through the collector to heat it. If the solar collector is in a freezing environment then the potable water must be drained to prevent freeze damage to the solar collectors. There are two methods of freeze protection for potable water in solar collector systems. The first method is to drain all of the water out of the solar collector during freezing conditions and second method is to supply heated water to the solar collector to keep the solar collector from freezing. The first method of freeze protection by draining the solar collector system includes two approaches, drain down and drain back. Drain down systems use a special "spool" valve to shut off the solar collector supply water and send the collector water down the drain. The drain back systems have a separate solar

collector fluid sump tank near the hot water tank. When the pump shuts off the fluid drains from the solar collector into this sump tank inside the home to prevent freezing. The second method of system freeze protection heats the solar collector water using electrical resistance heating elements external or internal, as integrated solar collector storage systems do, or provide heat by bleeding a small amount of hot water from the hot water tank through the solar collector continuously to keep it from freezing. Both of these types of heat adding systems must sense freezing conditions and take appropriate actions, which supply heat that costs money. Hence they are not freeze proof, as are antifreeze/water filled systems.

Main advantages of the invention using the pressurized antifreeze/water fluid loop are : 1) pressurized water/antifreeze heat transfer loop is freeze proof and allows the solar collector to operate up to 265 degrees Fahrenheit; 2) the high temperature heat transfer loop allows heat to be transferred with very low fluid flow rates minimizing pumping power and allowing small diameter tubes to take fluid to and from the solar collector and water tank heat exchanger; 3) internal double walled heat exchanger adapts to existing tanks with minimum re-plumbing and without tank removal or draining; 4) the fluid radiator, pressure relief, vacuum relief, overflow recovery system limits both solar collector temperature and fluid pressure while keeping the system full of fluid and keeping air out of the system to minimize corrosion; 5) double wall heat exchanger safely separates toxic heat transfer fluids from potable water; 6) this solar system has only one pump and is easier to install and maintain than two tank, two pump systems; and 7) The double walled internal hot water tank heat exchanger maintains normal tank stratification, maintaining the backup electrical or gas system efficiency.

SUMMARY OF INVENTION

In summary, the present invention is a pressurized fluid loop, where heat is collected in a solar panel illuminated by the sun, heats a solution of water based antifreeze or other suitable liquid, the fluid is pumped at low flow rate to a hot water tank where it gives up the heat via an internal heat exchanger, then returns to the solar collector at a low flow rate in small tubing. The fluid loop is pressurized and operates above the normal boiling point of water, 212 Fahrenheit, and automatically eliminates air from the heat transfer fluid loop. The fluid loop also has built in over-temperature and over-pressure protection, so if the fluid circulation pump stops, the solar collector will not get too hot and damage itself.

The primary objective of the present invention is to reduce the amount of material and complexity needed to collect and transport solar heat. This is accomplished by increasing the temperature in the fluid loop which allows more heat to be stored in each unit volume of fluid in the solar collector heat transfer loop. Hence a smaller volume of fluid at a lower flow rate is needed to deliver the heat from the solar collector to the hot water tank. The higher fluid temperature difference between the hot water tank and the fluid loop, decreases the surface area required for heat exchange inside of the hot water tank. The higher fluid loop temperature in the solar collector lowers the collector's efficiency by losing heat to the outside air. Flat plates lose more efficiency than evacuated tube solar collectors. This efficiency loss is tolerable for a system using significantly less material.

Another objective is to reduce the time and complexity of retrofitting solar energy to existing homes. The present invention uses flexible small diameter tubing to carry the low fluid flow volume. The small diameter of the fluid carrying tubes, approximately 3/8 inch outside diameter, also allows the tubes to be thermally insulated and still be less than 2 inches in diameter when bundled together. By adding an electrical wire bundle to the insulated fluid carrying tubes and placing them in a protective clam-shell covering, i.e. split pipe, an umbilical is created, which carries all fluids and electrical signals from the hot water tank to the solar collector. This "plug and play" umbilical allows do-it-yourselfers and professionals to install the system more quickly. These fluid carrying

tubes can be installed in existing buildings, because they are flexible and can be fed into and through attics, walls or placed on the outside of buildings.

Additional objectives, advantages and novel features of the invention will be set forth in part in the description which follows and in part will become apparent to those skilled in the art upon examination of the following. Others may be learned by practice of the invention. The objectives and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the pressurized loop solar collector system, including the fluid loop, the solar collector, the hot water tank heat exchanger, the fluid pump, fluid radiator, pressurization, overflow/recovery system, air elimination system and controller. The boiling activated radiator over-temperature and pressure activated over-temperature systems are shown schematically.

FIG. 2 is a view of the boiling activated radiator solar collector temperature limiting system and fluid pressurization, overflow/recovery system.

FIG. 3 is a pressure activated solar collector over-temperature control system, which upon loop boiling opens dampers in the solar collector to allow air-cooling.

FIG. 4 shows the details of a gas/liquid separator for the boiling activated radiator solar collector over-temperature system, which upon boiling forces steam and fluid from the main fluid loop into a liquid to air heat exchanger, a radiator, where it is cooled.

FIG. 5 is a plot of air valve position versus pressure in the solar collector fluid loop.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention (FIG. 1) consists of a pressurized heat transfer loop (1, 14 & 17), which operates well above the boiling point of water at one atmosphere of pressure, 212 degrees Fahrenheit. The heat transfer fluid (13) is heated in the solar collector tube (1) by the sun. The solar collector (2) can be single or double-glazed. The heated fluid then exits the solar collector in tube (1) and comes to a three-way connection. Path one (7) goes to the pressure actuator (6), which can move actuator arm (5) to actuate air dampers with motion (4). Path one may not be needed if the path two radiator is sufficient to prevent overheating. Path two goes through a radiator (8) with fins (9) to a pressure relief valve (10) which includes a vacuum recovery valve to let expelled heat exchanger fluid (13) back into the system from the fluid overflow/recovery reservoir (12), while excluding air. Path three (14) is the fluid tubing leading to the hot water tank (22) heat exchanger (16). The insertable, internal double walled heat exchanger screws into the tank through a tank port (24) and provides water tank fluid (30) ingress or egress via a side port (26). The inside of the outer heat exchanger wall (16) is in physical contact with the outside of tubes (14 &17). Physical contact means that over a significant area or approximately 50% of the surface, the interfaces are compressed together mechanically so heat can cross the interface, but leaking liquid from either side will move along the interface. Tube (14) turns around in the bottom of the heat exchanger and becomes tube (17) exiting the heat exchanger. Tubes (14 & 17) are much hotter than the water in the hot water tank (30) and are in physical contact with wall (16) so the heat is transferred from heat transfer fluid (13) through the first wall (14 or 17) then through the mechanical interface to the second wall (16) then into the water (30). Once tube (17) leaves the heat exchanger it returns to the pump (20) inlet where the fill/drain valve (18) is attached. On the upper side of the pump tube (17) intersects the purge valve (19), which allows the

system to be filled with fluid (13), using valves (18, 19 & 21). Tube (17) then returns to the solar collector tube (1) for heating of fluid (13).

To transport the pressurized fluid and the heat it contains from the solar collector to the hot water heater a flexible insulated umbilical is used (15). The umbilical consists of thermally insulated fluid connections (14 & 17) from the solar collector (1 & 2) to the hot water tank, rubber closed-cell thermal insulation (32), the low voltage electrical connections and a weather resistant covering of polymer pipe (31), i.e. ABS, which is split in half so it can be "clam-shelled" over the entire umbilical making one easy to install umbilical length. The two small diameter tubes (14 & 17) containing the solar collector heated fluid (13) are tied together along their length with plastic ties, i.e. "Zip Ties", or a polymer tape or coating to separate them. This allows the two-tube bundle to be flexible and insulated with about ¾ inch thick insulating jacket (32) and still be less than 2 inches in diameter. Adding a wire cable (34) to the outside of the umbilical allows sensor (50) to be easily connected to the controller or by adding wire cable (62) to the outside of the umbilical allows PV panel (60) to be connected to the pump (20) via the thermal cut off switch (64). The small diameter copper tubes are connected together with standard tubing unions, angles and T-connectors of about 3/8 inch size.

The system has two possible configurations for activating the heat transfer fluid pump (20). The first is a differential temperature control system run from household 115VAC power. This control system has a control box (52), which plugs into the wall outlet, has two low voltage input temperature sensors and an output needed to turn the pump on and off. When the solar collector temperature sensor (50) is hotter than the sensor (56) at the bottom of the hot water tank the controller turns the pump on. When the solar collector (sensor 50) is colder than the hot water tank (sensor 56) the controller turns the pump off. Sensor (56) also tells the controller the tank is getting too hot, ie if no one is home to use hot water, then the controller will shut the pump off even if the sun is shining. This would now cause the radiator (8 & 9) to protect the solar collector from over heating.

The second pumping system is based on using a photovoltaic array (60), which provides 12 Volt power when the sun is shining. This power is carried down to the pump on the umbilical connector wire (62). The pump is a DC powered pump, which is capable of low flow at modest pressures. There is no control box. When the sun is out the pump runs, when it is not, the pump stops. A thermal disconnect switch (64) is placed near the top of the hot water tank (22), so if the water gets too hot switch (64) will disconnect the pump.

The invention also consists of a radiator, a pressure relief and vacuum recovery valve and fluid overflow recovery system (Fig 2). This system includes a pressurized fluid radiator (8) with fins (9) and reservoir (12), a pressure cap (10) to regulate the pressure in the system and allow the overflowed fluid to return on system cool down at night via the relief valve in (10), which is connected to a fluid overflow and recovery reservoir (12) via tube (72). The pressure of the fluid in the solar collector heat transfer loop is regulated by the pressure cap, which uses a spring to push against the fluid pressure over a fixed area. During normal daily operation when the sun is out, the heat transfer fluid (13) expands as it heats from 75 degrees Fahrenheit to over 230 degrees Fahrenheit and when the pressure reaches the set pressure, i.e. 16 PSIG, fluid and trapped air overflows to the fluid overflow reservoir (12) via tube (72), which is vented to the atmosphere by a cap (70). At night, when the fluid in the solar heat transfer system cools and contracts, fluid only is drawn back through (10) into the heat transfer system to keep if full of fluid and keep air out. Air in the system can cause corrosion in the fluid loop. This simple system allows the nominal 50/50 water/antifreeze mixture in the solar heat transfer loop to heat up to over 212 degrees Fahrenheit, without boiling until it reaches almost 265 degrees Fahrenheit, at 16 PSIG confinement pressure. This high temperature allows for heat to be transferred more efficiently into the hot water tank, using lower flow rates and an internal (or external) hot water tank heat exchanger.

The invention also consists of a pressure activated solar collector over-temperature protection system (Fig 3). An integral part of the solar collector is a set of dampers (86 & 88) on both the top and bottom of the solar collector, which are opened by pressure actuator (6). These dampers are only open when the solar heat collected is more than the hot water tank can use. These dampers when opened allow outside air of less than 120 degrees Fahrenheit to flow over the solar absorber plate (Fig1. (3)), where the sunlight is converted to heat and transferred into the heat transfer fluid. This airflow cools the absorber and stops the boiling. Then the dampers close and the absorber heats back up. The dampers open and close on a 2 to 5 minute cycle and only minor boiling is allowed to take place. This self-controlling feature is unique and allows the solar collector to protect itself, even if the fluid flow in the pressurized fluid loop (Fig 1. (1, 14 & 17)) stops. The dampers (vents) can be used together with the boiling activated radiator over-temperature system as shown in Fig 4.

The pressure activated control system is needed if fluid circulation stops for any reason while the sun is shining, i.e. controller turns pump off, pump failure, fluid loop blockage. The pressure activation system consists of a solar system fluid pressure-activated actuator (6), such as a piston (84), or other pressure-activated actuator, which is in a retracted state at normal system operating pressure and in an extended state at the pressure cap relief setting, such as 16 PSIG. A spring (82) or pressurized cavity can be used to return the actuator to the retracted state, when the solar system pressure falls to atmospheric pressure. The solar system fluid (13) is sealed into the system via a bellows (80) or other acceptable seal, such as an O-ring. The actuator is connected to the fluid loop (7). This actuator output (5) is connected to a hinged or sliding valve (86 or 88) via a linkage (4), which allows air to flow over the solar collector absorber plate (Fig 1. (3)) to cool it off with outside air. Over-temperature protection is achieved by successive airflow vents over the solar collector absorber plate. When the solar collector gets too hot the heat transfer fluid (13) boils in the solar collector. This causes the pressure actuator to extend and open the solar collector air damper valves, which take the heat out of the solar collector and the heat transfer fluid. This action drops the solar collector

temperature below the boiling point and stops boiling. The system pressure returns to the set pressure and the actuator retracts and closes the solar collector air damper valves. This vent open/close cycle repeats itself until the sun goes down or the fluid flow resumes.

Figure 5 shows that the actuator and air valve position as a function of system pressure. The air valves are shut and the actuator retracted until a pressure of approximately 80% (102) of the maximum system pressure maintained by the pressure cap (Fig.4 (10)) is reached. At pressures above (102) the air valves begin to open and fully open when the system reaches 95% (104) of the system pressure (104) maintained by pressure cap (Fig.4 (10)). This arrangement allows the system to cool itself before vigorous boiling occurs. The pressure vs. actuator position profile is determined by the piston area (Fig 3. (84)) and spring (Fig 3. (82)) constant.

Figure 4 shows a boiling activated radiator solar collector over-temperature protection system. The system consists of a liquid to air radiator heat exchanger and a boiling gas separator. During normal operation the entire system is full of heat transfer fluid (13) and no boiling occurs. The liquid to air heat exchanger (8) with fins (9) is a side arm and normally has no fluid flow in it. Normally the fluid flows into the boiling gas separator (94) from the solar collector tube (1) and out of it in tube (14) down to the hot water tank heat exchanger. Under non-flow conditions, such as circulating pump failure or the solar input being greater than the hot water tank can use, the solar collector will begin to boil. In this event the boiling gas separator (94) allows the gas bubbles (steam) to go into the liquid to air heat exchanger (8), which stirs the liquid in the heat exchanger, while condensing the boiling gas. This heat in chamber (8) is conducted to the fins (9), which heats them above outside air temperature removing heat from the fluid in radiator (8). The filler tube (92) allows liquid to come from the liquid to air radiator (8) and be inserted below where the gas bubbles are being released tube (1) in the boiling gas separator (94), keeping the collector fluid loop (1, 14 & 17) full of liquid. The system

allows a small amount of boiling to take place, which rejects heat to the atmosphere via the liquid to air radiator heat exchanger. As long as boiling takes place the liquid in the radiator (8) will be heated by condensing the boiling gas. Only a small amount of fluid (13) will be forced through tube (72) into the fluid overflow reservoir (12). The advantage of this system is that it has no moving parts and can be made to dissipate all of the heat that the solar collector gathers from the sun.